

## CONTENTS

Abstract .....	1
1. Introduction .....	3
1.1. General introduction .....	3
1.2. Historical background on ELF-VLF emission study .....	4
1.3. Historical background on quasi-periodic ELF-VLF emission study...	5
2. Instrumentation and Observations .....	7
2.1. Outlines of observation system.....	7
2.1.1. Observation period from February 1974 to January 1975 .....	7
2.1.2. Observation period from September 1976 to September 1977...	8
2.1.3. Observation period from July 29, 1977 to September 18, 1977 at geomagnetic conjugate-pair stations.....	8
2.2. The device for finding the arrival directions of waves .....	10
2.2.1. Detection of the wide-band VLF signal.....	11
2.2.2. Direction analyzer .....	13
3. General Properties of QP Emissions .....	14
3.1. Diurnal variation of QP occurrences .....	17
3.2. Diurnal variation of QP periods .....	17
3.3. Diurnal variation of emission occurrences .....	19
3.4. $K_p$ dependence of QP occurrences .....	20
4. Classification of QP Emissions Based on Frequency-Time ( $f$ - $t$ ) Spectra...	22
4.1. Classification of QP emissions .....	22
4.2. Characteristics of each type of QP emissions .....	24
4.2.1. Characteristics of 'non-dispersive' type .....	24
4.2.2. Characteristics of 'rising-tone' types .....	29
4.2.3. Characteristics of the 'falling-tone' type of QP emissions.....	30
4.2.4. Characteristics of the 'mixed type' of QP emissions .....	30
4.2.5. Characteristics of the 'burst type' of QP emissions .....	33
4.3. Spectral structure at the onset time of a QP .....	33
5. Occurrence of QP Emissions Associated with Worldwide Geomagnetic Variations .....	36
5.1. Relationship between Type 1 QPs and worldwide geomagnetic variations .....	36
5.2. Relationship between Type 2 QPs and worldwide geomagnetic variations .....	39
5.3. SSC or SI triggered ELF-VLF emissions .....	40
6. Arrival Direction of ELF-VLF Chorus and QP Emissions .....	44
6.1. Arrival direction of ELF-VLF waves in individual examples.....	44
6.1.1. An example on December 31, 1974.....	45

6.1.2.	An example on December 29, 1974.....	46
6.1.3.	An example on January 23, 1975.....	46
6.1.4.	An example on January 28, 1975.....	47
6.2.	Statistical distribution of arrival direction.....	48
6.3.	Arrival direction of QP emissions.....	50
6.3.1.	The statistical arrival direction of Type 1 QP emissions .....	50
6.3.2.	Direction of arrival of QP elements.....	52
7.	Coordinated Observations of ELF-VLF Emissions at Two Separated Stations and at the Geomagnetic Conjugate-Pair Stations .....	56
7.1.	Distribution in intensity of ELF-VLF emissions simultaneously observed at Syowa and Mizuho Stations .....	56
7.1.1.	October 21, 1977 event .....	57
7.1.2.	Relationship between relative intensity at the two stations and arrival directions .....	58
7.1.3.	QP emissions .....	61
7.2.	Geomagnetic conjugacy of ELF-VLF emissions observed at Syowa Station, Antarctica and Husafell, Iceland .....	61
7.2.1.	Conjugacy of QP emissions seen on the band-limited intensity records .....	62
7.2.2.	Comparison of frequency-time spectra .....	64
7.2.3.	Conjugacy of the auroral chorus .....	66
7.2.4.	Conjugacy of the auroral hiss .....	69
8.	Relationships between QP Emissions and Magnetic Pulsations.....	71
8.1.	Comparison of dynamic spectra for intensities of QP emissions and magnetic pulsations .....	71
8.1.1.	Dynamic spectra for intensities of QP emissions and magnetic pulsations .....	71
8.1.2.	Dynamic spectra of Type 2 QP emissions .....	72
8.2.	Correlation between Type 1 QP emissions and Pc 3-4 magnetic pulsations .....	75
8.2.1.	Power spectrum and coherency.....	75
8.2.2.	Phase differences between QP emissions and magnetic pul- sations .....	80
8.3.	QP emissions associated with short period ( $T \sim 3-10$ s) magnetic pulsations .....	85
8.4.	Spectral characteristics of magnetic variations during Type 2 QP events .....	88
8.5.	Geomagnetic conjugacy of QP emissions and magnetic pulsations...	92
8.5.1.	Geomagnetic conjugacy of Type 1 QP emissions.....	92
8.5.2.	Geomagnetic conjugacy of Type 2 QP emissions.....	96
9.	Discussion .....	100

9.1. Generation region and modulation mechanism of Type 1 QP emissions.....	100
9.2. Generation region and modulation mechanism of Type 2 QP emissions.....	103
9.3. Models of spectral form for QP emissions .....	106
9.3.1. Model of ‘rising-tone’ and ‘falling-tone’ emissions.....	106
9.3.2. Model of ‘non-dispersive’ type QP emissions .....	108
10. Conclusions and Future Research.....	111
10.1. Summary and conclusions .....	111
10.1.1. Type 1 QP emissions.....	111
10.1.2. Type 2 QP emissions.....	112
10.2. Suggestions for future research .....	114
Acknowledgments.....	115
References .....	116